

# DECLARATION

I, Kiyoko Kono declare that:

1. I reside at c/o Saikyo Patent Office, Shikishima Building 6th Floor, 2-6, Bingomachi 3-chome, Chuo-ku, Osaka, Japan.

2. I understand and read both the Japanese and the English languages.

3. The attached is a full true and faithful English translation made by me of the priority document of the Japanese Patent Application No. 11-169339, filed on June 16, 1999.

4. I declare further that all statements made herein of my own knowledge are true, and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the above-identified application or any patent issuing thereon.

Date: June 25, 2003

Name: Kiyoko Kono  
Kiyoko Kono

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Applicant : SHARP KABUSHIKI KAISHA

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[INVENTOR]  
[Domicile or Residence] c/o SHARP KABUSHIKI KAISHA, 22-22,  
Nagaike-cho, Abeno-ku, Osaka-shi,  
Osaka  
[Name] Kazuhiko TSUDA

[INVENTOR]  
[Domicile or Residence] c/o SHARP KABUSHIKI KAISHA, 22-22,  
Nagaike-cho, Abeno-ku, Osaka-shi,  
Osaka  
[Name] Kazuhiro ISHIZUKA

[INVENTOR]  
[Domicile or Residence] c/o SHARP KABUSHIKI KAISHA, 22-22,  
Nagaike-cho, Abeno-ku, Osaka-shi,  
Osaka  
[Name] Hiroyuki OHGAMI

[APPLICANT FOR PATENT]  
[Identification No.] 000005049  
[Name] SHARP KABUSHIKI KAISHA  
[Phone] 06-6621-1221

[AGENT]  
[Identification No.] 100103296  
[Patent Attorney]  
[Name] Takaya KOIKE  
[Phone] 06-6621-1221  
[Office] Phone 043-299-8466  
Intellectual Property Division, Tokyo  
Intellectual Property Center

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[Item] Specification 1

[Item] Drawing(s) 1

[Item] Abstract 1

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SPECIFICATION

[TITLE OF THE INVENTION] METHOD OF MANUFACTURING LIQUID  
CRYSTAL DISPLAY APPARATUS

[CLAIMS]

[Claim 1] A method of manufacturing a liquid crystal display apparatus having, on one of a pair of substrates disposed so as to be opposed with a liquid crystal layer therebetween, reflecting means for reflecting incident light from the other substrate, comprising the steps of:

applying a positive photosensitive resin on one of the substrate;

forming asperities in a first region of the applied photosensitive resin film by exposing with various integrals of exposure amount so that the photosensitive resin in the first region is left in different film thicknesses, and forming in a second region of the applied photosensitive resin film a concave portion so that the photosensitive resin in the second region is left in a thickness smaller than those of the first region by exposing the second region with an integral of exposure amount different from those for the first region;

developing the exposed photosensitive insulator;

heat-treating the developed photosensitive resin; and

forming a reflecting film on the heat-treated

photosensitive resin.

[Claim 2] The method of manufacturing a liquid crystal display apparatus of claim 1, wherein a reflecting electrode comprising the reflecting film is formed in the first region of the photosensitive resin and that the reflecting electrode is connected to wiring formed in a lower layer of the reflecting electrode in the second region of the photosensitive resin.

[Claim 3] The method of manufacturing a liquid crystal display apparatus of claim 1, wherein a terminal portion is formed in an outside display region on one of the substrates and that the second region of the photosensitive resin is formed in the terminal portion.

[Claim 4] The method of manufacturing a liquid crystal display apparatus of claim 1, wherein the step of exposing the photosensitive resin includes a step of exposing the photosensitive resin using a photomask having a transmitting portion, a light intercepting portion and a semi-transmitting portion, to form the first region in regions corresponding to the light intercepting portion and semi-transmitting portion of the photomask, and the second region in a region corresponding to the transmitting portion of the photomask.

[Claim 5] The method of manufacturing a liquid crystal display apparatus of claim 1, wherein the step of exposing the photosensitive resin includes a step of exposing the photosensitive resin using a first photomask and a step of

exposing the photosensitive resin using a second photomask, to form the first region and the second region with the first and second photomasks, respectively.

[Claim 6] The method of manufacturing a liquid crystal display apparatus of claim 5, wherein the exposure amount at the step of exposing the photosensitive resin using the first photomask and the exposure amount at the step of exposing the photosensitive resin using the second photomask are the same.

[Claim 7] The method of manufacturing a liquid crystal display apparatus of claim 5, wherein uniform and low-illuminance exposure is performed at the step of exposing the photosensitive resin using the first photomask, while uniform and high-illuminance exposure is performed at the step of exposing the photosensitive resin using the second photomask.

[Claim 8] The method of manufacturing a liquid crystal display apparatus of claim 7, wherein circular or polygonal regions are irregularly disposed in the first photomask and that the total area of the circular or polygonal regions is in a range of from 20% to 40% of the total area of the photomask.

[Claim 9] The method of manufacturing a liquid crystal display apparatus of claim 8, wherein the circular or polygonal regions disposed in the first photomask are irregularly disposed so that the center-to-center distances between adjoining regions are in a range of from 5  $\mu\text{m}$  to 50  $\mu\text{m}$ .

[DETAILED DESCRIPTION OF THE INVENTION]

[0001]

[Technical field to which the invention belongs]

The present invention relates to a method of manufacturing a liquid crystal display apparatus which carries out display by reflecting externally incident light.

[0002]

[Prior art]

In recent years, application of liquid crystal display apparatuses to word processors, laptop personal computers, pocket televisions and the like has rapidly been progressing. Of the liquid crystal display apparatuses, reflective-type liquid crystal display apparatuses which carry out display by reflecting externally incident light are attracting attention because the reflective-type liquid crystal display apparatuses are low in power consumption, thin and capable of being reduced in weight since no backlight is necessary.

[0003]

However, in the conventional reflective-type liquid crystal display apparatuses, the brightness and the contrast ratio of the display are dependent on the use environment such as ambient brightness or the use condition. Therefore, at present, high expectations are placed on the realization of a reflective-type liquid crystal display apparatus that has excellent reflection characteristics, can easily be

manufactured with excellent reproducibility and is high in display quality.

[0004]

Japanese Unexamined Patent Publication JP-A 6-75238 discloses a technology to form random and high-density asperities on a reflecting electrode in order to improve the display quality of the reflective-type liquid crystal display apparatus.

[0005]

According to this, a resin layer for adding fine asperities to a reflecting electrode comprises a first photosensitive resin layer patterned with random asperities and a second photosensitive resin layer for making the asperities smoother, and in a mask for patterning the first photosensitive resin layer, circular light intercepting portions are randomly disposed and the total area of the light intercepting portions is not less than 40% of the area of the reflecting plate.

[0006]

By increasing the randomness as described above, the interference due to the repetitive pattern is prevented and the reflecting light is prevented from being colored, and by increasing the density of the asperities, the area of the flat part is reduced to thereby reduce the regular reflection component.

[0007]

Moreover, Japanese Unexamined Patent Publication JP-A 9-90426 discloses a technology to simultaneously expose an asperity forming pattern and contact holes using only one layer of a positive photosensitive resin in order to reduce the process of manufacturing a reflective-type liquid crystal display apparatus.

[0008]

A method of manufacturing a reflective-type liquid crystal display apparatus described in this patent publication will briefly be described with reference to the drawings.

[0009]

Fig. 13 is a cross-sectional view showing the structure of a reflective-type liquid crystal display apparatus formed by the manufacturing method described in the above-mentioned patent publication. Fig. 14 shows cross-sectional views showing the flow of the manufacturing process.

[0010]

As shown in Fig. 13, in the reflective-type liquid crystal display apparatus described in the above-mentioned patent publication, a substrate in which a liquid crystal driving device 24 is formed is used as a reflecting substrate 23, and the following are provided: an aluminum pixel electrode 10 disposed on the reflecting substrate 23; a transparent electrode 12 opposed thereto; a color filter substrate 25 supporting the transparent electrode 12; liquid crystal 11

sandwiched therebetween; a retardation film 15 disposed above the color filter substrate (on the side of the surface not opposed to the liquid crystal); and a polarizer 16 disposed above the retardation film 15.

[0011]

In the reflecting substrate 23, an amorphous silicon transistor is formed on a glass substrate 1 as the liquid crystal driving device 24. As shown in Fig. 13, the liquid crystal driving device 24 comprises Ta as a gate electrode 2 on the glass substrate 1, SiNx as a gate insulating layer 3, a-Si as a semiconductor layer 4, n-type a-Si as an n-type semiconductor layer 5, Ti as a source electrode 7, and Ti as a drain electrode 8.

[0012]

A method of manufacturing the reflecting substrate 23 of the reflective-type liquid crystal display apparatus described in the above-mentioned patent publication will be described with reference to Fig. 14.

[0013]

First, as shown in Fig. 14(a), a positive photosensitive resin 9 is applied to the substrate 1.

[0014]

Then, as shown in Fig. 14(b), exposure is carried out at high illuminance using a photomask having transmitting portions 18 corresponding to the contact hole 30 and, in addition

thereto, transmitting portions 18 at asperity formed portions, as shown in Fig. 15.

[0015]

Then, as shown in Fig. 14(c), by development with a developing solution, the resin in the exposed parts mentioned above is completely removed, so that a resin configuration that is positive with respect to the mask pattern is formed.

[0016]

Then, as shown in Fig. 14(d), by a heat treatment, the resin in the exposed regions is deformed into smooth asperities. However, at this time the exposed regions are flat because the resin has completely been removed by the above-described developing step.

[0017]

Then, as shown in Fig. 14(e), an Al thin film is formed as the reflecting electrode 10, and patterning is performed so that one reflecting electrode 10 corresponds to one transistor.

[0018]

The reflecting electrode 10 of the reflective-type liquid crystal display apparatus described in the above-mentioned patent publication is formed by the above-described process. In such a reflecting substrate 23, since the asperities are formed with the positive photosensitive resin in the exposed portions having been completely removed, the area of the flat part is large. In such a reflecting plate in which

the area of the flat part is large, since the light source is reflected in the flat region, the regular reflection component is large. Since display is difficult to confirm when the light source is reflected, the regular reflection component generally is avoided in the case of the reflective-type display apparatus.

[0019]

Therefore, the regular reflection component of the reflecting plate in the reflective-type liquid crystal display apparatus disclosed in the above-mentioned patent publication do not contribute to the brightness, which results in dark display.

[0020]

[Problems that the invention is to solve]

Compared to the reflective-type liquid crystal display apparatus disclosed in JP-A 9-90426, previously-mentioned JP-A 6-75238 discloses a reflective-type liquid crystal display apparatus adopting a complicated asperity forming process in order to create an ideal scattering condition by improving the density of the asperities of the reflecting plate. According to this apparatus, after application of a first positive photosensitive resin, first exposure development of a sufficient intensity is performed. Then, after the patterning of the asperities are completely performed, the clearances of the asperities are completely filled so that the asperities are smooth. Then, a second positive photosensitive resin is

applied in order to reduce the area of the flat part, and thereafter, only the patterning of the contact hole portions is again performed by performing second exposure development.

[0021]

However, in this process, since the photosensitive resin is applied in two layers, it is necessary to perform the photoprocess (application - exposure - development - heat treatment) of the photosensitive resin twice, so that the cost clearly increases.

[0022]

Further, in the reflective-type liquid crystal display apparatus disclosed in JP-A 9-90426, since one layer of a positive photosensitive resin is used, it is necessary to perform the photoprocess of the photosensitive resin only once, so that the process is simplified and cost reduction can be achieved. However, since it is necessary to remove certainly the photosensitive resin in the contact hole portions, it is inevitable that the positive photosensitive resin in the exposed area in the asperity forming pattern portion is also removed. Consequently, the exposed area is flat, so that in the reflecting plate, the density of the asperities is low and the regular reflection component is large.

[0023]

The invention is made to solve the above-mentioned problems of the reflective-type liquid crystal display

apparatus, and an object thereof is to provide a method of manufacturing a liquid crystal display apparatus with which a reflecting plate having excellent reflection characteristics can easily be manufactured with excellent reproducibility, whereby the display quality is improved.

[0024]

[Means of solving the problems]

In order to achieve the above-mentioned object, the invention provides a method of manufacturing a liquid crystal display apparatus having, on one of a pair of substrates disposed so as to be opposed with a liquid crystal layer therebetween, reflecting means for reflecting incident light from the other substrate, comprising the steps of:

applying a positive photosensitive resin on one of the substrate;

forming asperities in a first region of the applied photosensitive resin film by exposing with various integrals of exposure amount so that the photosensitive resin in the first region is left in different film thicknesses, and forming in a second region of the applied photosensitive resin film a concave portion so that the photosensitive resin in the second region is left in a thickness smaller than those of the first region by exposing the second region with an integral of exposure amount different from those for the first region;

developing the exposed photosensitive insulator;

heat-treating the developed photosensitive resin; and forming a reflecting film on the heat-treated photosensitive resin.

[0025]

In the above-mentioned method of manufacturing a liquid crystal display apparatus, it is preferable that a reflecting electrode comprising the reflecting film is formed in the first region of the photosensitive resin film and that the reflecting electrode is connected to wiring formed in a lower layer of the reflecting electrode in the second region of the photosensitive resin film.

[0026]

Further, it is also preferable that a terminal portion is formed in an outside display region on one of the substrates and that the second region of the photosensitive resin film is formed in the terminal portion.

[0027]

Still further, it is also preferable that the step of exposing the photosensitive resin includes a step of exposing the photosensitive resin using a photomask having a transmitting portion, a light intercepting portion and a semi-transmitting portion, to form the first region in regions corresponding to the light intercepting portion and semi-transmitting portion of the photomask, and the second region in a region corresponding to the transmitting portion of the

photomask.

[0028]

Yet further, it is also preferable that the step of exposing the photosensitive resin includes a step of exposing the photosensitive resin using a first photomask and a step of exposing the photosensitive resin using a second photomask, to form the first region and the second region with the first and second photomasks, respectively.

[0029]

At this time, it is also preferable that the exposure amount at the step of exposing the photosensitive resin using the first photomask and the exposure amount at the step of exposing the photosensitive resin using the second photomask are the same.

[0030]

Moreover, it is also preferable that uniform and low-illuminance exposure is performed at the step of exposing the photosensitive resin using the first photomask, while uniform and high-illuminance exposure is performed at the step of exposing the photosensitive resin using the second photomask.

[0031]

Furthermore, it is also preferable that circular or polygonal regions are irregularly disposed in the first photomask and that the total area of the circular or polygonal

regions is in a range of from 20% to 40% of the total area of the photomask.

[0032]

Still more, it is also preferable that the circular or polygonal regions disposed in the first photomask are irregularly disposed so that the center-to-center distances between adjoining regions are in a range of from 5  $\mu$ m to 50  $\mu$ m.

[0033]

Now, descriptions over how the method of manufacturing a liquid crystal display apparatus of the invention works are given below.

[0034]

According to the invention, by exposing the regions of different patterns of the photosensitive resin applied to the substrate with different integrals of exposure amount on an area basis, a smooth region having high-density asperities and other regions having no high-density asperities can be formed with a reduced number of steps.

[0035]

That is, there are hardly any flat parts in the asperities formed region because the asperities formed region can be formed into a curved surface by a heat treatment under a condition that there is no part in which the photosensitive resin is completely removed. Consequently, excellent reflection characteristics

with a reduced regular reflection component can be realized.

[0036]

At the exposing step, since the positive photosensitive resin in the part intercepted from light by a photomask (light intercepted region) is not readily soluble in a developing solution, circular or polygonal pillars or holes are formed, and since the positive photosensitive resin in the part not intercepted from light by the photomask (transmitting region) is readily soluble in the developing solution, a photosensitive resin film having asperities is formed on the substrate in correspondence with the transmitting region and the light intercepted region of the photomask by developing the photosensitive resin with the developing solution after the exposure.

[0037]

Owing to the use of the photosensitive resin as an interlayer insulating film, the reflecting electrode can be manufactured by a minimum number of steps. By forming the reflecting electrode in the first region of the photosensitive resin film and connecting the reflecting electrode to the wiring formed in the lower layer of the reflecting electrode in the second region of the photosensitive resin film, that is, removing the resin in regions corresponding to contact holes for connecting the reflecting electrode and a liquid crystal driving device, the photosensitive resin is left over the entire

display picture element region except the contact holes, so that asperities having a smaller flat part and a smooth surface can be formed. As a result, bright reflected light with reduced regular reflection can be obtained.

[0038]

Further, owing to the use of the photosensitive resin as an interlayer insulating film and the formation of a transmitting region corresponding to the terminal portion for inputting an external signal in the second region of the photosensitive resin, the terminal portion can be manufactured by a minimum number of steps.

[0039]

Since the step of exposing the photosensitive resin includes the step of exposing the photosensitive resin using the photomask having the transmitting portion, the light intercepting portion and the semi-transmitting portion, to form the first region in the regions corresponding to the light intercepting portion and semi-transmitting portion of the photomask and the second region in the region corresponding to the transmitting portion of the photomask, the number of exposures can be reduced to one.

[0040]

Further, since the step of exposing the photosensitive resin includes the step of exposing the photosensitive resin using the first photomask and the step of exposing the

photosensitive resin using the second photomask, to form the first and second regions by the first and second photomasks, it is made possible to use photomasks composed of only a transmitting portion and a light intercepting portion, with the result that the design and manufacture of the photomasks is facilitated and the number of exposing steps can be reduced.

[0041]

According to the invention, since the exposure with the first photomask and the exposure with the second photomask are carried out in the same exposure amount, the light quantity adjustment is facilitated, with the result that the throughput of the exposing step can be enhanced.

[0042]

By performing the uniform and low-illuminance exposure at the step of exposing the photosensitive resin using the first photomask and performing the uniform and high-illuminance exposure at the step of exposing the photosensitive resin using the second photomask, it becomes possible that only the second region is exposed at a high illuminance independently of an optimum exposure condition for the first region, so that it is possible to completely remove the photosensitive resin with more reliability in the first region. Here, the high-illuminance exposure indicates an exposure performed with an exposure amount where a sensitizer that restrains the dissolution of the resin in the developing solution is made

sufficiently soluble in the positive photosensitive resin and the left film amount after the development is substantially 0%, and the low-illuminance exposure indicates an exposure performed with an exposure amount where the solubilization of the sensitizer that restrains the dissolution of the resin in the developing solution is not sufficiently performed in the positive photosensitive resin and the left film amount after the development is 0% or more and less than 50%, preferably, not in a range of from 10% to 50% of the film thickness before the development.

[0043]

More specifically, in the positive photosensitive resin formed on the substrate, owing to the low-illuminance exposure with the first photomask, the sensitizer in the part subjected to the exposure of a low illuminance with the first photomask is not sufficiently solubilized, so that the film of the part subjected to the low-illuminance exposure is uniformly reduced in thickness by the development with the developing solution after the exposure.

[0044]

Moreover, in the positive photosensitive resin formed on the substrate, owing to the high-illuminance exposure with the second photomask, the sensitizer in the part subject to the exposure of a high illuminance using the second photomask is sufficiently solubilized, so that the photosensitive resin on

the substrate is completely removed by the development with the developing solution after the exposure. This enables the connection between the reflecting electrode formed at a succeeding step and a TFT drain electrode.

[0045]

As described above, owing to the high-illuminance exposure, the low-illuminance exposure and development on one layer of a positive photosensitive resin and heat-treatment of the photosensitive resin, the asperities of the photosensitive resin formed on the substrate are deformed by heat, with the result that continuous, high-density and smooth asperities without any flat part are formed on the substrate.

[0046]

Further, by forming the reflecting electrode on the heat-treated photosensitive resin having the smooth asperities, excellent reflecting means with a small regular reflection component can be formed.

[0047]

In the invention, the order of the steps of the low-illuminance exposure and the high-illuminance exposure, that is, the order of the first exposing step and the second exposing step may be opposite to the above-described order.

[0048]

As the process from the exposing step to the developing step, the following two are considered: the process from

exposure (the low-illuminance exposure and the high-illuminance exposure) to development; and the process from exposure (the low-illuminance exposure or the high-illuminance exposure) through development and exposure (the high-illuminance exposure or the low-illuminance exposure) to development. In the invention, either of the two processes can be used. However, the former process is preferable in view of the simplification of the process.

[0049]

Further, since the circular or polygonal regions are irregularly disposed in the first photomask, the total area of the circular or polygonal regions is in a range of from 20% to 40% of the total area of the photomask and the circular or polygonal regions are irregularly disposed, the periodicity of the pattern of the asperities of the photosensitive resin formed on the substrate is eliminated, so that the light interference phenomenon can be prevented. As a result, white scattered light without any color can be obtained. Moreover, since the scattered light from the asperities does not biased in a specific direction, uniform scattered light can be obtained.

[0050]

Since the total area of the circular or polygonal regions in the first photomask is in a range of from 20% to 40% of the photomask, the angle of inclination of the asperities of the photosensitive resin formed on the substrate can be controlled

so that the light can efficiently be used.

[0051]

Here, the total area of the photomask concretely means the total area of the reflecting electrode. In the case where the area of the circular or polygonal regions in the first photomask is not less than 40%, when the circular or polygonal regions are randomly disposed, adjoining circular or polygonal regions overlap each other into a large pattern, so that the pattern density decreases as a whole and the ratio of the area of the flat part increases. As a result, a reflecting plate with a large regular reflection component is formed. In the case where the area of the circular or polygonal regions in the first photomask is not more than 20%, when the circular or polygonal regions are randomly disposed, the distances between adjoining circular or polygonal regions are too large, so that the distances between convex portions and convex portions or concave portions and concave portions of the configuration of the photosensitive resin formed by development are too large and flat parts are left between convex portions or concave portions when the resin is deformed by heating. As a result, a reflecting plate with a large regular reflection component is formed. From these, in the invention, the total area of the circular regions in the first photomask is in a range of from 20% to 40% of the total area of the photomask.

[0052]

Here, by irregularly disposing the circular or polygonal regions disposed in the first photomask so that the center-to-center distances between adjoining regions are in a range of from 5  $\mu\text{m}$  to 50  $\mu\text{m}$ , a sufficient number of asperity patterns can be disposed for one picture element of the liquid crystal display apparatus, so that scattered light can be obtained in which there is no difference in characteristics between picture elements.

[0053]

In the case where adjoining circular or polygonal regions are disposed so as not to overlap each other, patterns in which the center-to-center distance is not more than 5  $\mu\text{m}$  are not resolved but become flat because of the limit of resolution of the exposure machine, so that a reflecting plate with a large regular reflection component is formed. Generally, in a liquid crystal display apparatus, since the size of one picture element is not more than approximately 100  $\mu\text{m} \times 300 \mu\text{m}$ , to dispose approximately ten or more convex portions or concave portions for one picture element in order to obtain uniform scattering property, it is necessary that the center-to-center distance is substantially not more than 50  $\mu\text{m}$ . When the center-to-center distance is larger than 50  $\mu\text{m}$ , since the distances between the circular regions are large, the ratio of the area of the flat part increases, so that a reflecting plate with a large regular reflection component is formed. From these, in

the invention, the circular or polygonal regions disposed in the first photomask are irregularly disposed so that the center-to-center distances between adjoining circular or polygonal regions are in a range of from 5  $\mu\text{m}$  to 50  $\mu\text{m}$ .

[0054]

[Working examples]

(Embodiment 1)

Now referring to the drawings, a reflective-type liquid crystal display apparatus of Embodiment 1 of the invention is described below. Fig. 1 is a plan view showing a reflecting substrate of a reflective-type liquid crystal display apparatus according to Embodiment 1. Fig. 2 is a cross-sectional view of the reflecting substrate shown in Fig. 1. Fig. 3 shows cross-sectional views showing the flow of the manufacturing process of the substrate.

[0055]

As shown in Figs. 1 and 2, on the reflecting substrate 23 used in the reflective-type liquid crystal display apparatus according to this embodiment, a reflecting electrode 10 is formed, and the surface thereof has smooth asperities comprising circular concave or convex portions 33. On a glass substrate 1, an amorphous silicon transistor is formed as a liquid crystal driving device 24. The liquid crystal driving device 24 comprises Ta as a gate electrode 2 on the glass substrate 1, SiNx as a gate insulating layer 3, a-Si as a

semiconductor layer 4, n-type a-Si as an n-type semiconductor layer 5, Ti as a source electrode 7, and Ti as a drain electrode 8.

[0056]

A signal input terminal portion 27 for inputting signals to a gate bus line and a source bus line comprises a terminal portion electrode 2 of Ta and a terminal connection electrode 26 of ITO formed by patterning simultaneously with the gate bus line and the gate electrode.

[0057]

A manufacturing process of the reflecting substrate 23 of the reflective-type liquid crystal display apparatus according to this embodiment will be described with reference to Fig. 3. In these figures, the pixel region is shown on the left side, and the signal input terminal portion region is shown on the right side.

[0058]

First, as shown in Fig. 3(a), a positive photosensitive resin 9 (the name of the product: OFPR-800 manufactured by Tokyo Ohka Kogyo Co., Ltd.) is applied to the glass substrate 1 in a thickness of 1 to 5  $\mu\text{m}$ . In this embodiment, the resin 9 was applied in a thickness of 3  $\mu\text{m}$ .

[0059]

Then, by using a first photomask 19 in which the area of light intercepting portions 17 was in a range of from 20%

to 40% as circular regions as shown in Fig. 4, exposure was uniformly performed at a low illuminance as shown in Fig. 3(b). It is desirable that the exposure amount at this time is 20 mj to 100 mj. In this embodiment, exposure was performed with an exposure amount of 40 mj. At this time, the circular or polygonal light intercepting portions 17 of the first photomask 19 were randomly disposed so that the center-to-center distances between adjoining light intercepting portions 17 were in a range of from 5  $\mu$ m to 50  $\mu$ m, preferably, 10  $\mu$ m to 20  $\mu$ m.

[0060]

Then, by using a second photomask 20 in which transmitting portions 18 corresponding to the contact hole portions 30 were opened as shown in Fig. 5, the contact hole portions were uniformly exposed at a high illuminance as shown in Fig. 3(c). At this time, the second photomask 20 also serves as a transmitting portion with respect to the signal input terminal portion 27, and the terminal portion 27 was exposed at a high illuminance simultaneously with the exposure of the contact holes. It is desirable that the exposure amount at this time is 160 mj to 500 mj. In this embodiment, exposure was performed with an exposure amount of 240 mj.

[0061]

Then, as shown in Fig. 3(d), by performing development with a developing solution TMAH

(tetramethylammoniumhydroxide) manufactured by Tokyo Ohka Kogyo Co., Ltd., the resin in the part exposed at a high illuminance (the contact hole portions and the signal input terminal portion) was completely removed, approximately 40%, with respect to the initial film thickness, of the resin in the part exposed at a low illuminance was left, and approximately 80%, with respect to the initial film thickness, of the resin in the unexposed part was left.

[0062]

Then, as shown in Fig. 3(e), by performing a heat treatment at 200°C for 60 minutes, the resin of the above-described condition was deformed into smooth asperities.

[0063]

Then, as shown in Fig. 3(f), an Al thin film was formed by sputtering as the reflecting electrode 10 on the substrate 1 in a thickness of 2000 Å, and as shown in Figs. 3(g) to (k), patterning was performed so that one reflecting electrode 10 corresponds to one transistor.

[0064]

Specifically, the photoresist 28 was applied as shown in Fig. 3(g), a portion to be removed for separation of each pixel electrode and the signal input terminal portion 27 were exposed as shown in Fig. 3(h), and development, etching and exfoliation were performed as shown in Figs. 3(i) to (k) to thereby perform patterning of the Al thin film serving as the

reflecting electrode 10.

[0065]

By the above-described process, the reflecting electrode 10 having smooth and high-density asperities was formed. In such a reflecting substrate 23, the area of the flat part is reduced, so that ideal reflection characteristics with a small regular reflection component can be realized. Moreover, the number of photoprocesses of the photosensitive resin can be reduced, so that the cost necessary for the manufacture of the reflecting plate can be reduced.

[0066]

Lastly, the reflecting substrate 23 and a color filter substrate for supporting a transparent electrode are bonded together with a spacer therebetween in a manner similar to that of the prior art, liquid crystal is filled, and a retardation film and a polarizer are bonded to the color filter substrate to complete the reflective-type liquid crystal display apparatus according to this embodiment.

[0067]

(Embodiment 2)

Hereinafter, a reflective-type liquid crystal display apparatus according to Embodiment 2 of the invention will be described with reference to the drawings. The reflecting substrate of the reflective-type liquid crystal display apparatus according to this embodiment is the same as the

reflecting substrate shown in Fig. 1 but is formed by a different manufacturing method. The manufacturing method will be described with reference to the cross-sectional views shown in Fig. 6.

[0068]

Fig. 6 shows cross-sectional views showing a manufacturing process of the reflecting substrate used in the reflective-type liquid crystal display apparatus according to this embodiment. In these figures, the pixel region is shown on the left side, and the signal input terminal portion region is shown on the right side.

[0069]

First, as shown in Fig. 6(a), the positive photosensitive resin 9 (the name of the product: OFPR-800 manufactured by Tokyo Ohka Kogyo Co., Ltd.) is applied to the glass substrate 1 in a thickness of 1 to 5  $\mu\text{m}$ . In this embodiment, the resin 9 was applied in a thickness of 3  $\mu\text{m}$ .

[0070]

Then, by using a photomask 35 in which light intercepting portions 17, transmitting portions 18 and a semi-transmitting portion 29 coexisted and the area of the light intercepting portions 17 was in a range of from 20% to 40% as circular regions as shown in Fig. 7, exposure was uniformly performed at a high illuminance as shown in Fig. 6(b). It is desirable that the exposure amount at this time is 160 mj to 500 mj. In this

embodiment, exposure was performed with an exposure amount of 240 mj. At this time, the area of the circular or polygonal light intercepting portions 17 of the photomask was 30%, the light intercepting portions 17 were randomly disposed so that the center-to-center distances between adjoining light intercepting portions 17 were in a range of from 5  $\mu\text{m}$  to 50  $\mu\text{m}$ , preferably, 10  $\mu\text{m}$  to 20  $\mu\text{m}$ , the transmitting portions 18 were disposed in the regions corresponding to the contact holes 30, and the semi-transmitting portion 29 whose light transmittance was 17% of that of the transmitting portions was disposed in the other regions. Although not shown, the region other than the display region is a transmitting region.

[0071]

The succeeding process is similar to that of the above-described Embodiment 1. Development was performed as shown in Fig. 6(c), and a heat treatment was performed as shown in Fig. 6(d), so that smooth asperities were formed by the resin deformed.

[0072]

Then, as shown in Fig. 6(e), an Al thin film was formed as the reflecting electrode 10 on the substrate 1, and as shown in Figs. 6(f) to (j), patterning was performed so that one reflecting electrode 10 corresponds to one transistor.

[0073]

By the above-described process, the reflecting electrode

10 having smooth and high-density asperities was formed. In such a reflecting substrate 23, the area of the flat part is reduced, so that ideal reflection characteristics with a small regular reflection component can be realized. Moreover, the number of photoprocesses of the photosensitive resin can be reduced, so that the cost necessary for the manufacture of the reflecting plate can be reduced.

[0074]

Lastly, the reflecting substrate 23 and a color filter substrate for supporting a transparent electrode are bonded together with a spacer therebetween in a manner similar to that of the prior art, liquid crystal is filled, and a retardation film and a polarizer are bonded to the color filter substrate to complete the reflective-type liquid crystal display apparatus according to this embodiment.

[0075]

In the reflective-type liquid crystal display apparatus according to this embodiment, while the reflecting electrode having smooth and high-density asperities is formed like in the above-described Embodiment 1, the number of exposures can further be reduced by using the photomask having the semi-transmitting portions in the photoprocess of the photosensitive resin, and the cost necessary for the manufacture of the reflecting substrate can be reduced.

[0076]

(Embodiment 3)

Hereinafter, a reflective-type liquid crystal display apparatus according to Embodiment 3 of the invention will be described with reference to the drawings. The reflecting substrate of the reflective-type liquid crystal display apparatus according to this embodiment is the same as the reflecting substrate shown in Fig. 1 but is formed by a different manufacturing method. The manufacturing method will be described with reference to the cross-sectional views shown in Fig. 8.

[0077]

Fig. 8 shows cross-sectional views showing a manufacturing process of the reflecting substrate used in the reflective-type liquid crystal display apparatus according to this embodiment. In these figures, the pixel region is shown on the left side, and the signal input terminal portion region is shown on the right side.

[0078]

First, as shown in Fig. 8(a), the positive photosensitive resin 9 (the name of the product: OFPR-800 manufactured by Tokyo Ohka Kogyo Co., Ltd.) is applied to the glass substrate 1 in a thickness of 1 to 5  $\mu\text{m}$ . In this embodiment, the resin 9 was applied in a thickness of 3  $\mu\text{m}$ .

[0079]

Then, by using the first photomask 19 so that the area

of the light intercepting portions 17 was in a range of from 20% to 40% as circular regions as shown in Fig. 4, exposure was uniformly performed at a low illuminance as shown in Fig. 8(b). It is desirable that the exposure amount at this time is 20 mj to 100 mj. In this embodiment, exposure was performed with an exposure amount of 40 mj. At this time, the circular or polygonal light intercepting portions 17 of the first photomask 19 were randomly disposed so that the center-to-center distances between adjoining light intercepting portions 17 were in a range of from 5  $\mu$ m to 50  $\mu$ m, preferably, 10  $\mu$ m to 20  $\mu$ m.

[0080]

Then, by using the second photomask 20 in which the transmitting portions 18 corresponding to the contact hole portions 30 were opened as shown in Fig. 5, the contact hole portions were uniformly exposed with an exposure amount of 40 mj which was the same as that in the above-described first exposure process as shown in Fig. 8(c).

[0081]

Then, as shown in Fig. 8(d), by performing development with a developing solution TMAH (tetramethylammoniumhydroxide) manufactured by Tokyo Ohka Kogyo Co., Ltd., approximately 2% (0.06  $\mu$ m) of the resin in the part exposed twice (the contact hole portions and the signal input terminal portion) was left, approximately 40%, with

respect to the initial film thickness, of the resin in the part exposed once was left, and approximately 80%, with respect to the initial film thickness, of the resin in the unexposed part was left.

[0082]

Then, as shown in Fig. 8(e), by performing a heat treatment at 200°C for 60 minutes, the resin of the above-described condition was deformed into smooth asperities.

[0083]

Then, as shown in Fig. 8(f), by exposing the substrate to an oxygen plasma atmosphere for five minutes in a dry etching apparatus, the outermost surface of the photosensitive resin was etched to be reduced in thickness by 0.1  $\mu\text{m}$  as a whole, so that the resin in the contact hole portions and the signal input terminal portion was completely removed. This process was performed because approximately 2% of the photosensitive resin was left in the contact hole portions. However, this process is unnecessary when the resin is completely removed after the development.

[0084]

The succeeding process is similar to that of the above-described Embodiments 1 and 2. As shown in Fig. 8(g), an Al thin film was formed as the reflecting electrode 10 on the substrate 1, and as shown in Figs. 8(h) to (l), patterning was performed so that one reflecting electrode 10 corresponds

to one transistor.

[0085]

By the above-described process, the reflecting electrode 10 having smooth and high-density asperities was formed. In such a reflecting substrate 23, the area of the flat part is reduced, so that ideal reflection characteristics with a small regular reflection component can be realized. Moreover, the number of photoprocesses of the photosensitive resin can be reduced, so that the cost necessary for the manufacture of the reflecting plate can be reduced.

[0086]

Lastly, the reflecting substrate 23 and a color filter substrate for supporting a transparent electrode are bonded together with a spacer therebetween in a manner similar to that of the prior art, liquid crystal is filled, and a retardation film and a polarizer are bonded to the color filter substrate to complete the reflective-type liquid crystal display apparatus according to this embodiment.

[0087]

In the reflective-type liquid crystal display apparatus according to this embodiment, while the reflecting electrode having smooth and high-density asperities is formed like in the above-described Embodiment 1, the throughput of the apparatus is enhanced by performing the first and the second exposures with the same exposure amount in the photoprocess of the

photosensitive resin, and the cost necessary for the manufacture of the reflecting substrate can be reduced.

[0088]

(Embodiment 4)

Hereinafter, a transmissive/reflective type liquid crystal display apparatus according to Embodiment 4 of the invention will be described with reference to the drawings. Fig. 9 is a plan view showing a substrate of the transmissive/reflective type liquid crystal display apparatus according to this embodiment. Fig. 10 is a cross-sectional view of the substrate shown in Fig. 9. Fig. 11 shows cross-sectional views showing the flow of the manufacturing process of the substrate.

[0089]

As shown in Figs. 9 and 10, in the substrate 23 used in the transmissive/reflective type liquid crystal display apparatus according to this embodiment, one pixel electrode formed on the substrate 23 is divided into a reflecting region in which the reflecting electrode 10 is formed and a transmitting region 31 in which a transparent electrode is formed. The reflecting electrode 10 has on the surface thereof smooth asperities comprising the circular concave or convex portions like in Embodiments 1 to 3.

[0090]

With this structure, the transmissive/reflective type

liquid crystal display apparatus according to this embodiment can be used as a reflective-type liquid crystal display apparatus when the ambient light is so strong that the display is dimmed in a transmissive liquid crystal display apparatus, and can be used as a transmissive liquid crystal display apparatus by turning on the backlight when the display cannot be clearly viewed in the reflective-type liquid crystal display apparatus because of a dim environment.

[0091]

In the transmissive/reflective type liquid crystal display apparatus according to this embodiment, as shown in Figs. 9 and 10, an amorphous silicon transistor is formed on the glass substrate 1 as the liquid crystal driving device 24. The liquid crystal driving device 24 comprises Ta as the gate electrode 2 on the glass substrate 1, SiNx as the gate insulating layer 3, a-Si as the semiconductor layer 4, n-type a-Si as the n-type semiconductor layer 5, the source electrode 7 and the drain electrode 8 made of ITO, and a Ta layer 32 formed on the electrodes 7 and 8. The ITO of the drain electrode 8 is extended to the pixel region to form the transparent electrode 32 formed in the transmitting region.

[0092]

Although not shown in this embodiment, the signal input terminal portion 27 for inputting signals to the gate bus line and the source bus line is similar to those of the above-

described Embodiments 1 to 3.

[0093]

A manufacturing process of the substrate 23 of the transmissive/reflective type liquid crystal display apparatus according to this embodiment will be described with reference to Fig. 11.

[0094]

First, as shown in Fig. 11(a), the positive photosensitive resin 9 (the name of the product: OFPR-800 manufactured by Tokyo Ohka Kogyo Co., Ltd.) is applied to the glass substrate 1 in a thickness of 1 to 5  $\mu\text{m}$ . In this embodiment, the resin 9 was applied in a thickness of 3  $\mu\text{m}$ .

[0095]

Then, by using the first photomask 19 in which the area of the light intercepting portions 17 was in a range of from 20% to 40% as circular regions as shown in Fig. 4, exposure was uniformly performed at a low illuminance as shown in Fig. 11(b). It is desirable that the exposure amount at this time is 20 mj to 100 mj. In this embodiment, exposure was performed with an exposure amount of 40 mj using the first photomask 19 in which the area of the light intercepting portions 17 was 30%. At this time, the circular or polygonal light intercepting portions 17 of the first photomask 19 were randomly disposed so that the center-to-center distances between adjoining light intercepting portions 17 were in a range of from 5  $\mu\text{m}$  to 50

$\mu\text{m}$ , preferably, 10  $\mu\text{m}$  to 20  $\mu\text{m}$ .

[0096]

Then, by using a second photomask 34 in which transmitting portions 18 corresponding to the contact hole portions 30 and the transmitting region 31 were opened as shown in Fig. 12, the contact hole portions 30 and the transmitting region 31 were uniformly exposed at a high illuminance as shown in Fig. 11(c). At this time, the second photomask had a transmitting portion with respect to the signal input terminal portion, and the terminal portion 27 was exposed at a high illuminance simultaneously with the exposure of the contact holes and the transmitting portion. It is desirable that the exposure amount at this time is 160 mj to 500 mj. In this embodiment, exposure was performed with an exposure amount of 240 mj.

[0097]

Then, as shown in Fig. 11(d), by performing development with a developing solution TMAH (tetramethylammoniumhydroxide) manufactured by Tokyo Ohka Kogyo Co., Ltd., the resin in the exposed part (the contact hole portions, the transmitting region and the signal input terminal portion) was completely removed, approximately 40%, with respect to the initial film thickness, of the resin in the part exposed at a low illuminance was left, and approximately 80%, with respect to the initial film thickness, of the resin in the

unexposed part was left.

[0098]

Then, as shown in Fig. 11(e), by performing a heat treatment at 200°C for 60 minutes, the resin of the above-described condition was deformed into smooth asperities.

[0099]

The succeeding process is similar to that of the above-described Embodiments 1 to 3. As shown in Fig. 11(f), an Al thin film was formed as the reflecting electrode 10 on the substrate 1, and patterning was performed so that one reflecting electrode 10 corresponds to one transistor.

[0100]

By the above-described process, the substrate was formed that had the reflecting region comprising the reflecting electrode 10 having smooth and high-density asperities, and the transmitting region comprising the transparent electrode. In the reflecting electrode on the substrate, the area of the flat part is reduced, so that ideal reflection characteristics with a small regular reflection component can be realized. Moreover, the number of photoprocesses of the photosensitive resin can be reduced, so that the cost necessary for the manufacture of the reflecting plate can be reduced.

[0101]

Lastly, the substrate 23 and a color filter substrate for supporting a transparent electrode are bonded together with

a spacer therebetween in a manner similar to that of the prior art, liquid crystal is filled, and a retardation film and a polarizer are bonded to the color filter substrate to complete the transmissive/reflective type liquid crystal display apparatus according to this embodiment.

[0102]

[Effect of the invention]

According to the invention, by exposing one layer of a photosensitive resin applied to the substrate with the different integrals of exposure amount on an area basis, smooth and high-density asperities can be formed, so that ideal reflecting means with a reduced flat area and a small regular reflection component can be formed. Consequently, the number of photoprocesses of the photosensitive resin can be reduced to thereby reduce the cost necessary for the manufacture.

[0103]

In the invention, since a positive photosensitive resin is used, when the low-illuminance exposure is performed with the photomask, the reaction progresses from the surface of the photosensitive resin, so that dissolution readily progresses from the surface when the reacting portion is dissolved by the development, and in the case where it is necessary to control the film reduction amount like in the invention, the control can easily be performed while the adhesion to the substrate is maintained.

[BRIEF EXPLANATION OF THE DRAWINGS]

[Fig. 1]

Fig. 1 is a plan view of a reflecting substrate used in a reflective-type liquid crystal display apparatus according to an embodiment of the invention.

[Fig. 2]

Fig. 2 is a cross-sectional view of the reflecting substrate used in the reflective-type liquid crystal display apparatus according to an embodiment of the invention.

[Fig. 3]

Figs. 3(a) to (k) are cross-sectional views showing a manufacturing process of the reflecting substrate used in the reflective-type liquid crystal display apparatus according to an embodiment of the invention.

[Fig. 4]

Fig. 4 is a schematic plan view showing the patterns of a transmitting region and light intercepting region of a first photomask according to an embodiment of the invention.

[Fig. 5]

Fig. 5 is a schematic plan view showing the patterns of transmitting region and a light intercepting region of a second photomask according to an embodiment of the invention.

[Fig. 6]

Figs. 6(a) to (j) are cross-sectional views showing a manufacturing process of the reflecting substrate used in a

reflective-type liquid crystal display apparatus according to an embodiment of the invention.

[Fig. 7]

Fig. 7 is a schematic plan view showing the pattern of a photomask according to an embodiment of the invention.

[Fig. 8]

Figs. 8(a) to (l) are cross-sectional views showing a manufacturing process of the reflecting substrate used in the reflective-type liquid crystal display apparatus according to an embodiment of the invention.

[Fig. 9]

Fig. 9 is a plan view of a reflecting substrate used in a transmissive/reflective type liquid crystal display apparatus according to an embodiment of the invention.

[Fig. 10]

Fig. 10 is a cross-sectional view of the reflecting substrate used in the transmissive/reflective type liquid crystal display apparatus according to an embodiment of the invention.

[Fig. 11]

Figs. 11(a) to (f) are cross-sectional views showing a manufacturing process of the reflecting substrate used in the transmissive/reflective type liquid crystal display apparatus according to an embodiment of the invention.

[Fig. 12]

Fig. 12 is a schematic plan view showing the patterns of a transmitting regions and light intercepting regions of a first photomask according to an embodiment of the invention.

[Fig. 13]

Fig. 13 is a cross-sectional view showing the reflective-type liquid crystal display apparatus formed by the conventional manufacturing method.

[Fig. 14]

Figs. 14(a) to (e) are cross-sectional views showing the manufacturing process of the reflecting substrate in the conventional reflective-type liquid crystal display apparatus.

[Fig. 15]

Fig. 15 is a schematic plan view showing the patterns of the transmitting regions and the light intercepting region of the conventional photomask.

[Reference numerals]

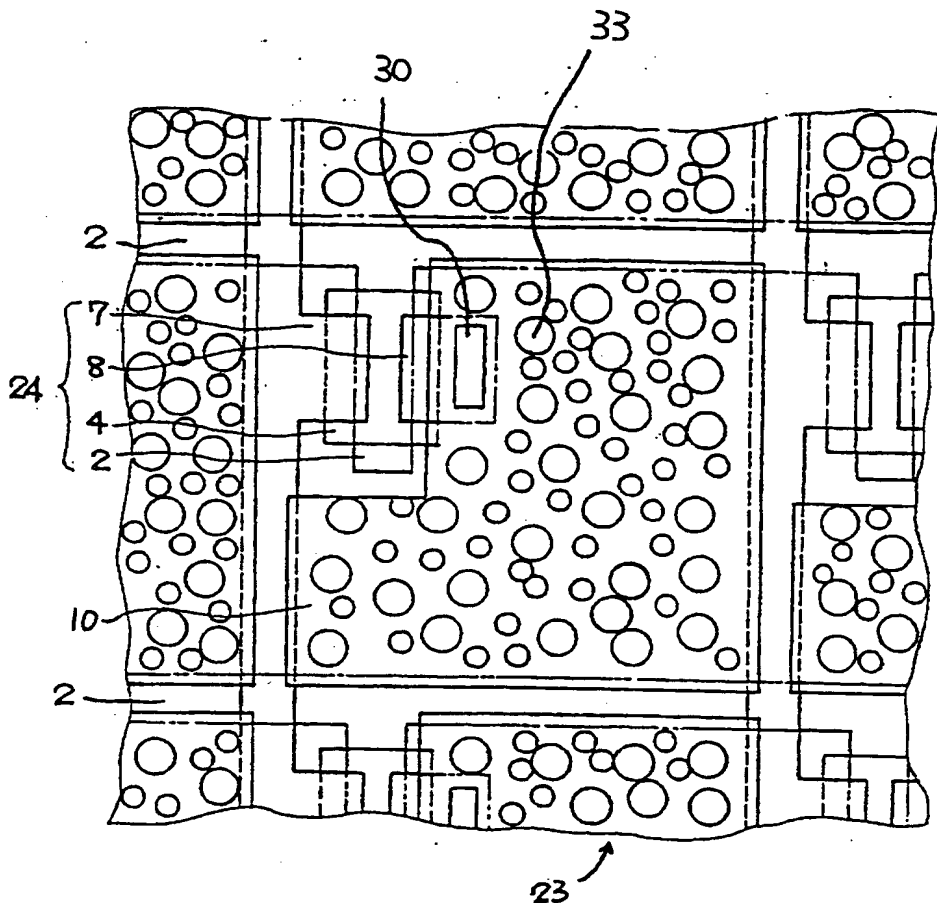
- 1        glass substrate
- 2        gate line, gate electrode, terminal electrode  
         made of the same material as that of gate  
         electrode
- 3        gate insulating layer
- 4        semiconductor layer
- 5        n-type semiconductor layer
- 6        etch stopper
- 7        source electrode

8 drain electrode  
9 insulating layer between layers (positive  
photosensitive resin)  
10 reflecting electrode  
11 liquid crystal layer  
12 ITO electrode  
13 color filter  
14 glass plate on the side of color filter  
15 retardation film  
16 polarizer  
17 light intercepting portion  
18 transmitting portion  
19 first photomask  
20 second photomask  
21 photomask  
22 UV light  
23 reflecting substrate  
24 liquid crystal driving device  
25 color filter substrate  
26 terminal connection electrode  
27 signal input terminal portion  
28 photoresist  
29 semi-transmitting portion  
30 contact hole  
31 transmitting region

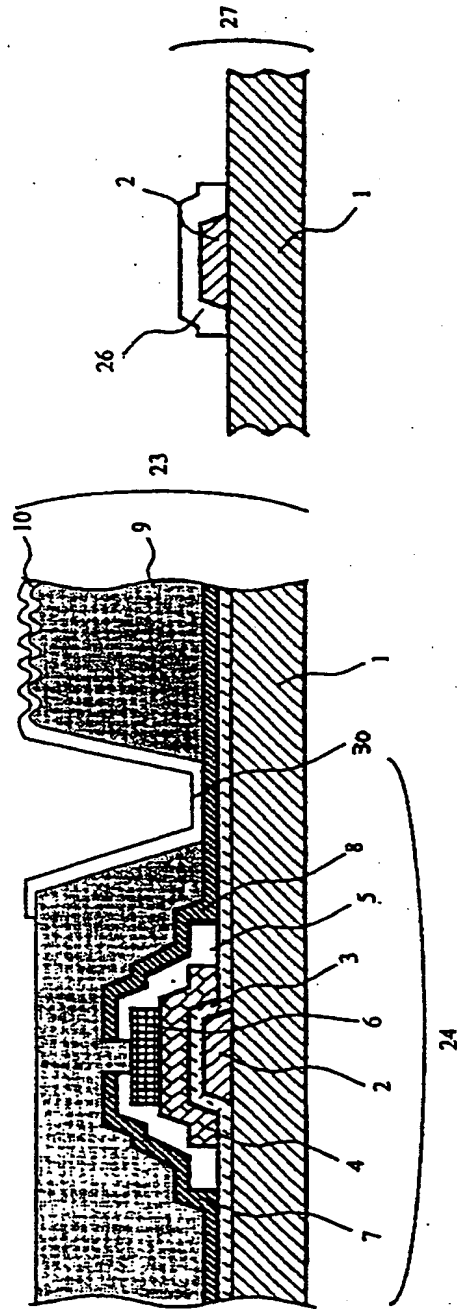
- 32 metal layer
- 33 concave or convex portion
- 34 second photomask
- 35 photomask

[DOCUMENT] DRAWINGS

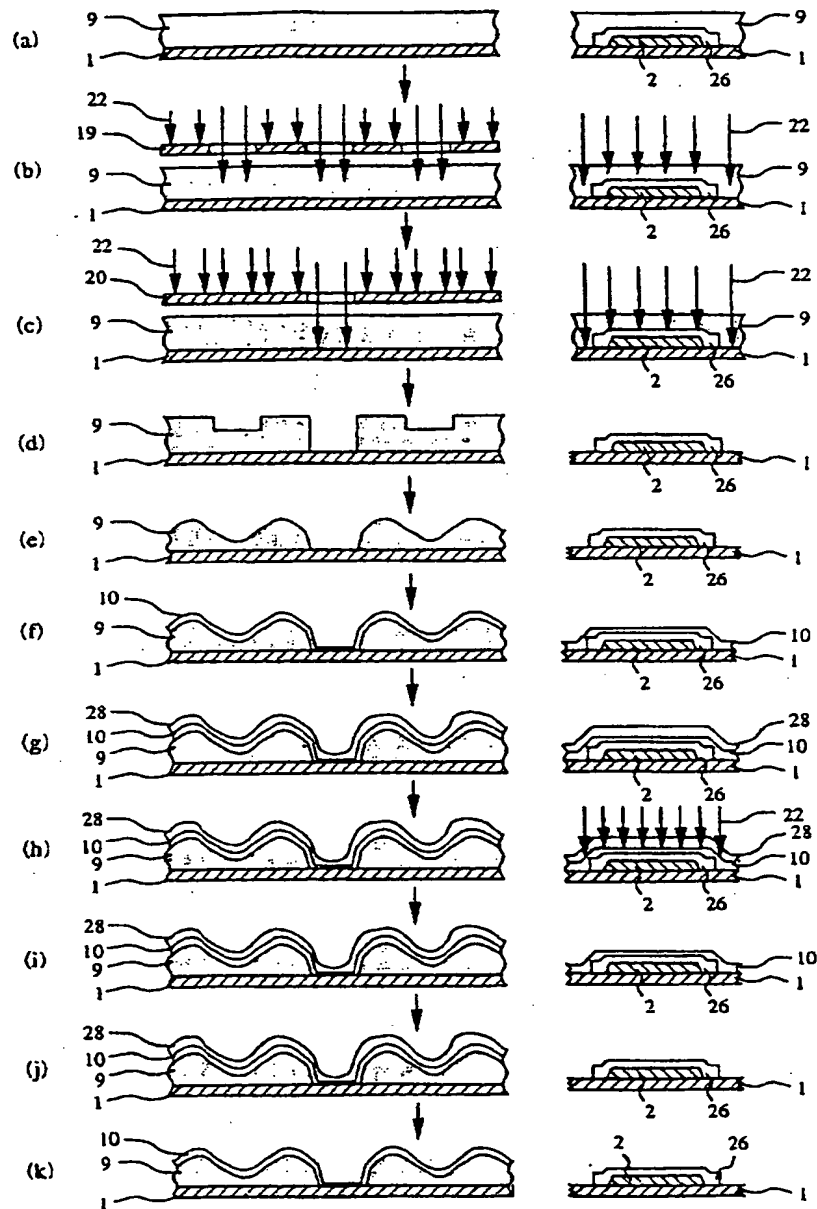
[Fig. 1]



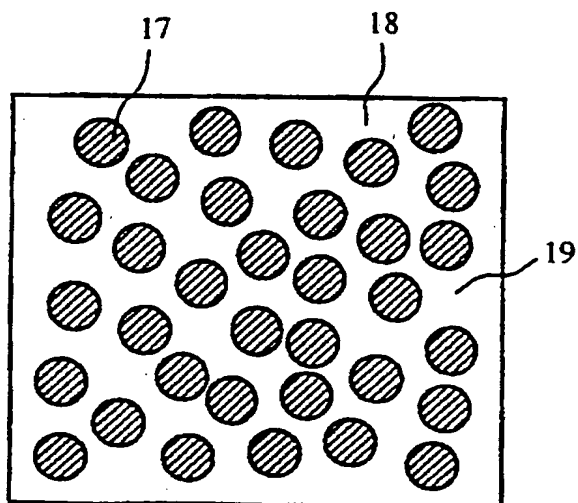
[Fig. 2]



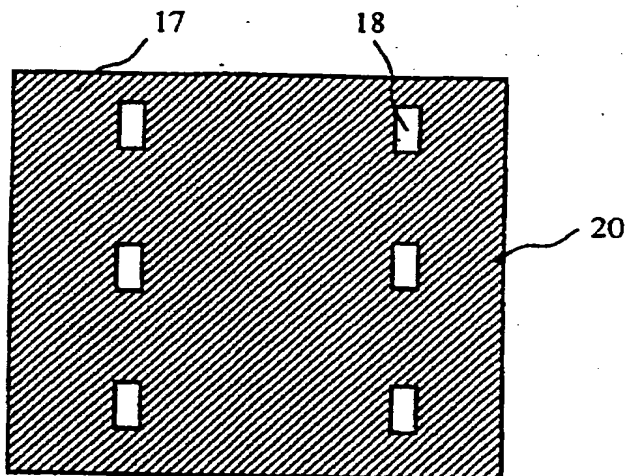
[Fig. 3]



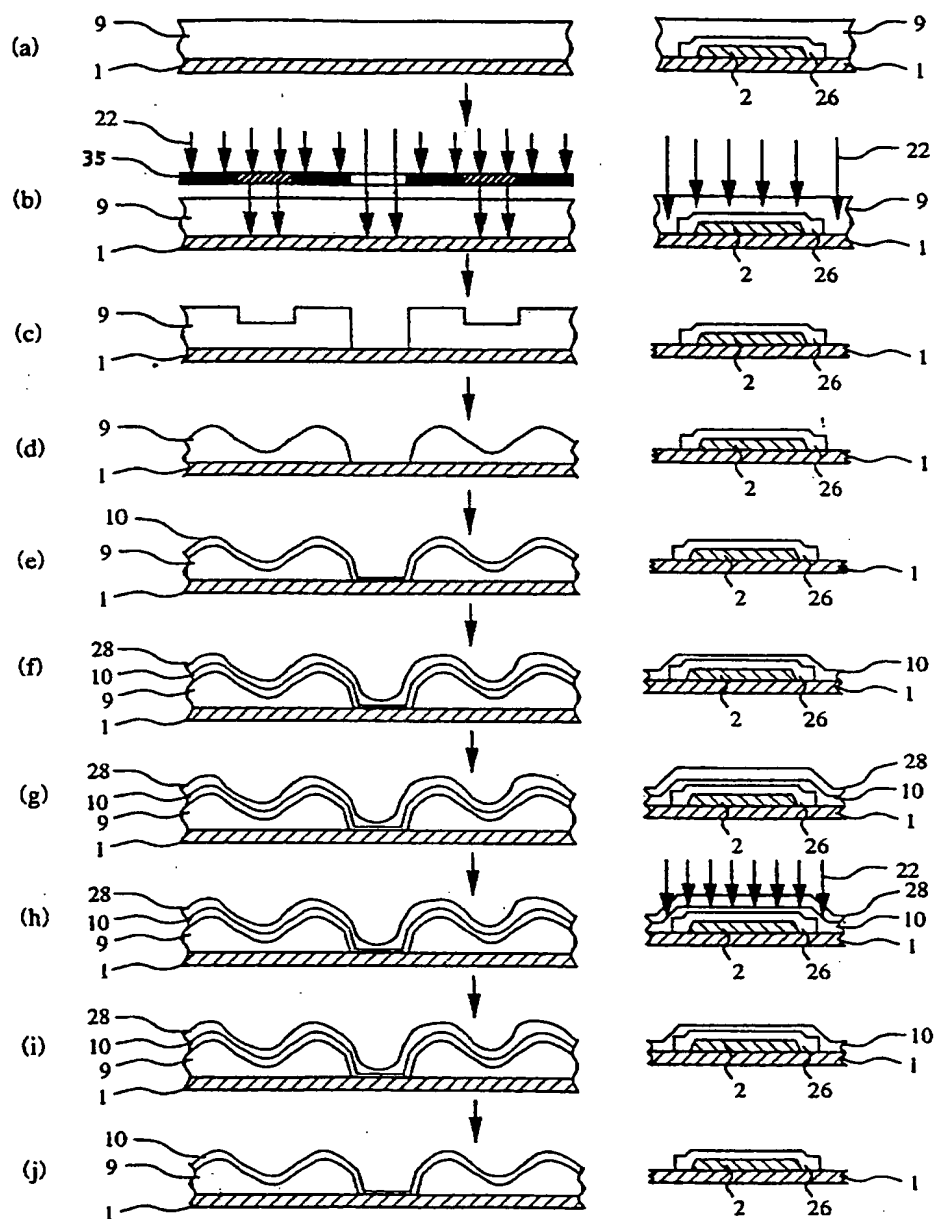
[Fig. 4]



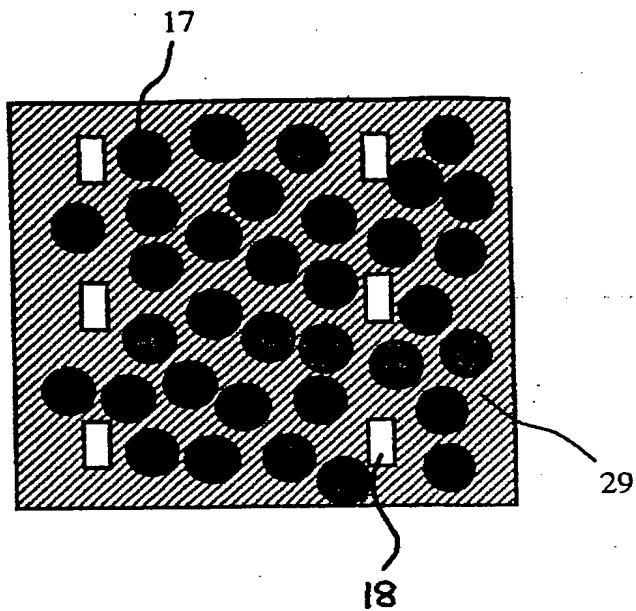
[Fig. 5]



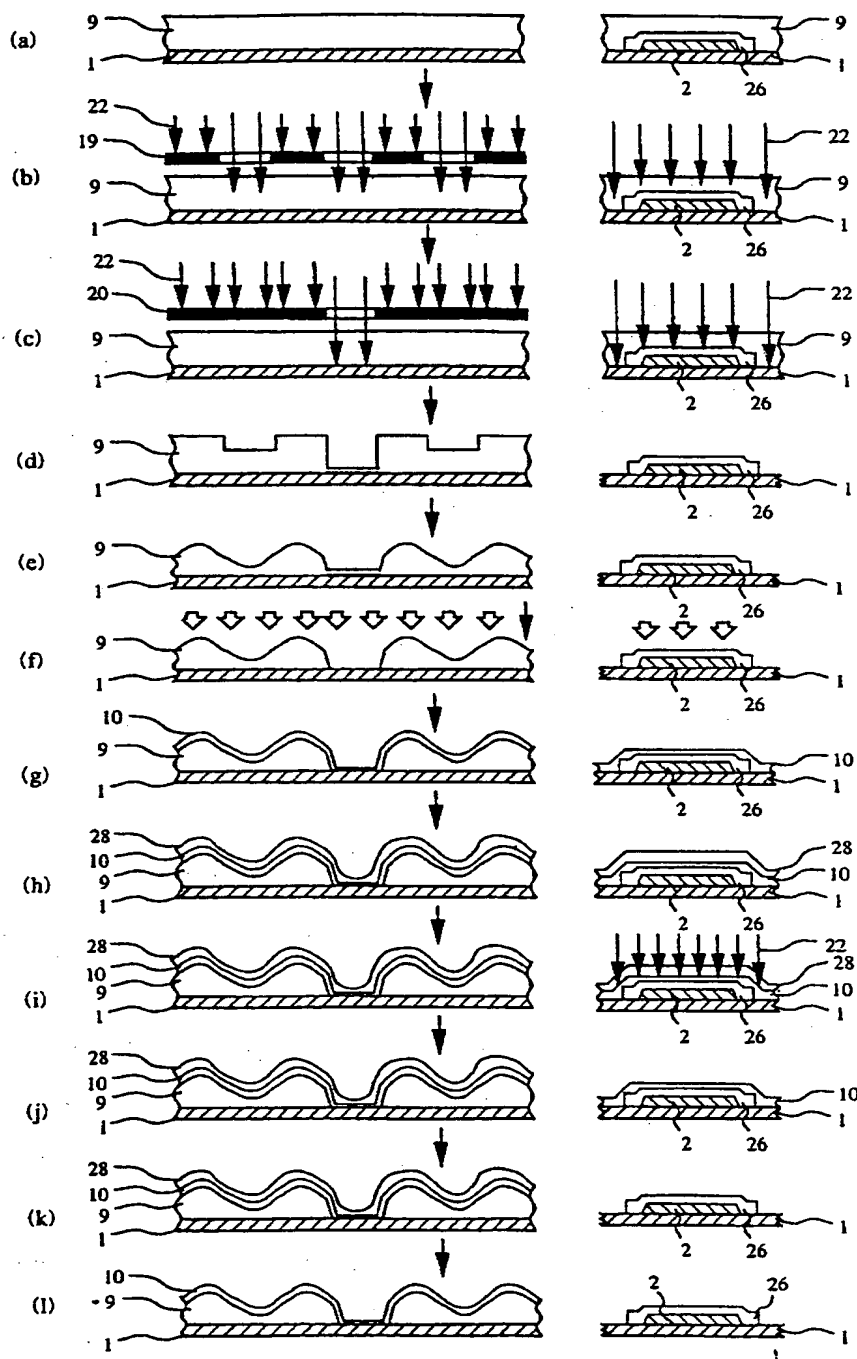
[Fig. 6]



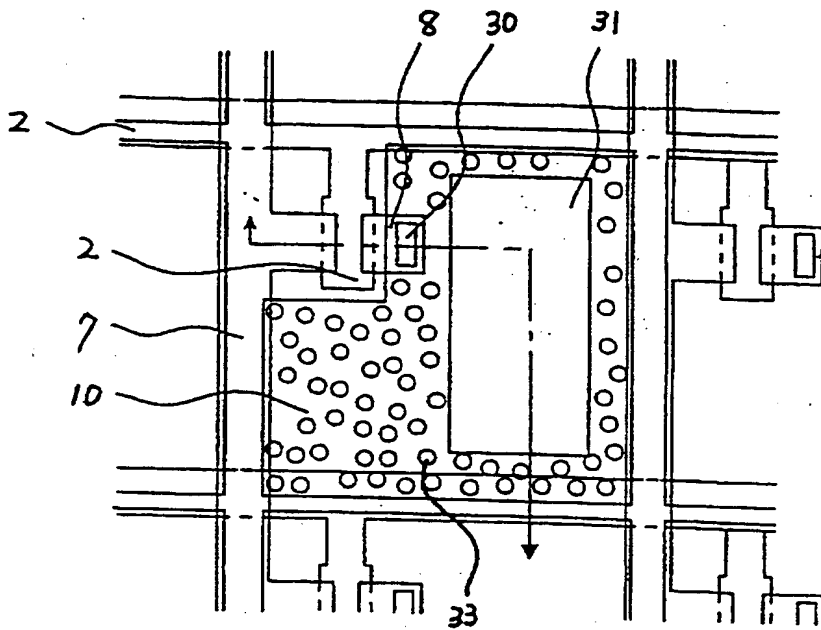
[Fig. 7]



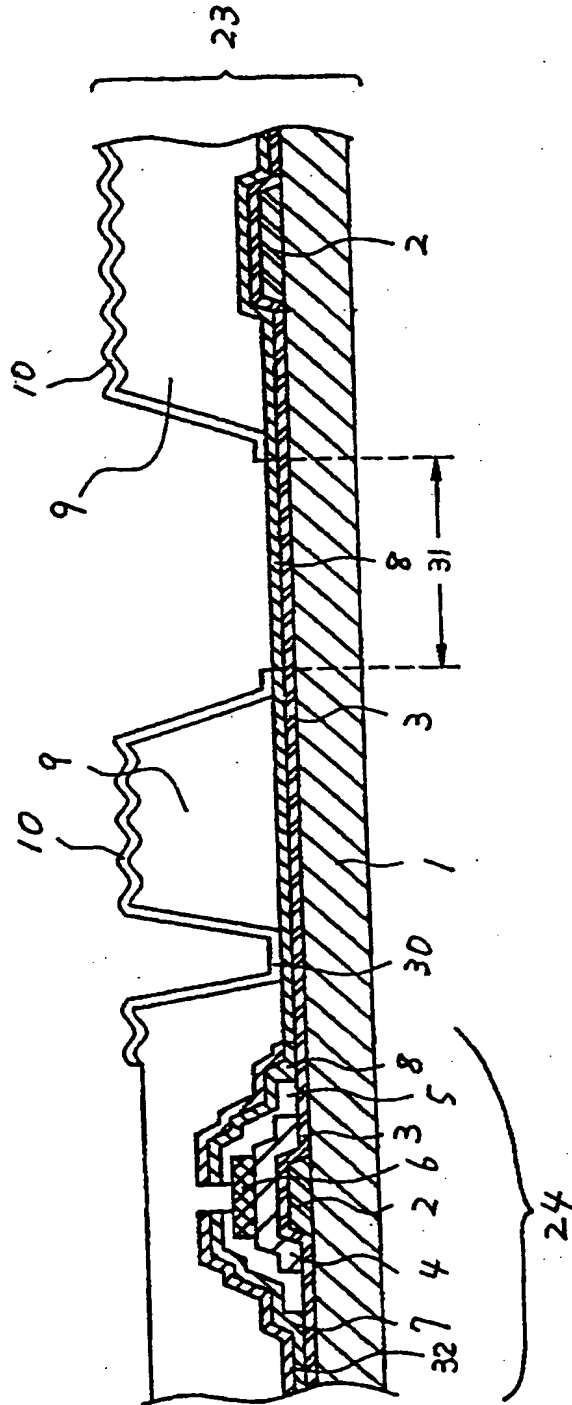
[Fig. 8]



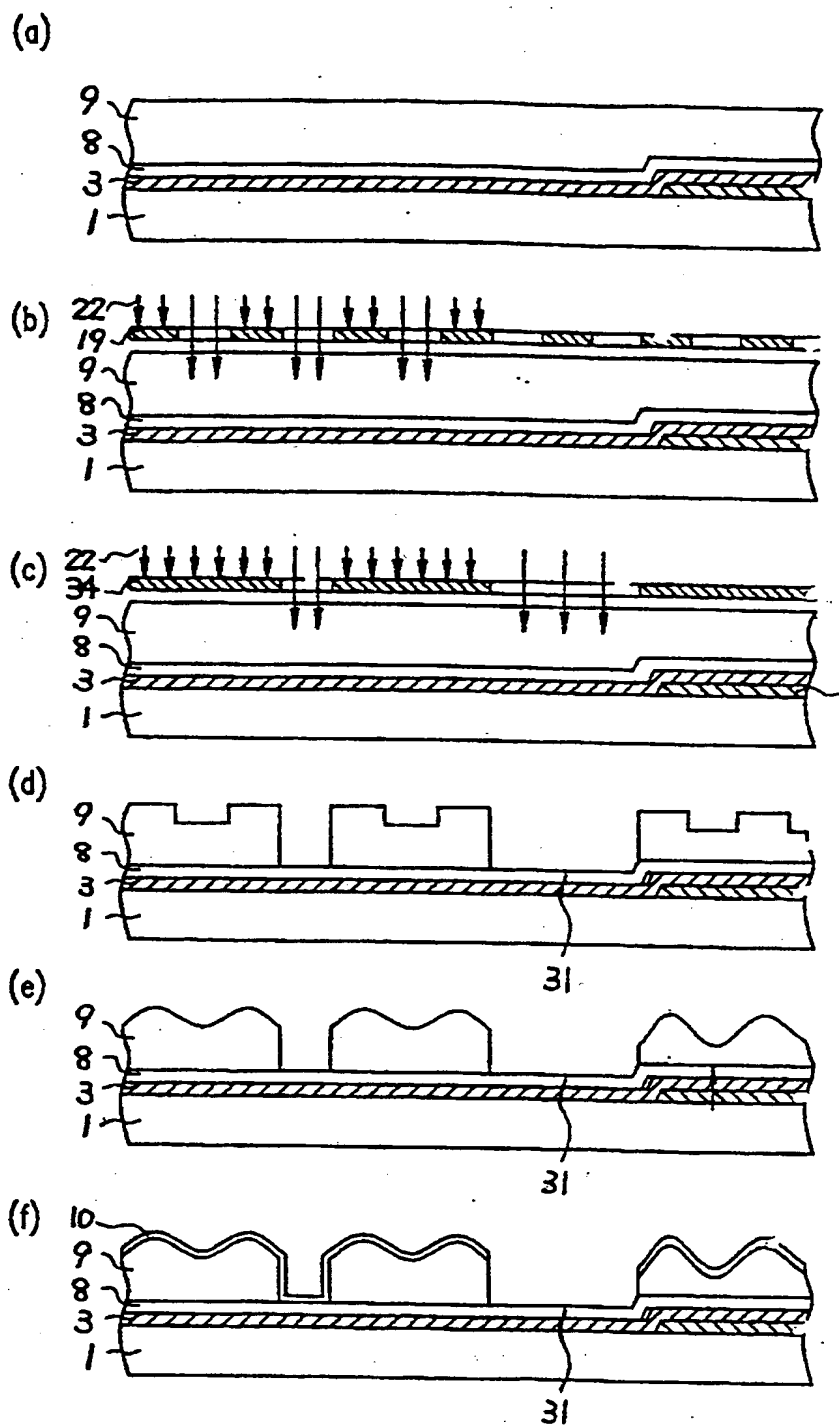
[Fig. 9]



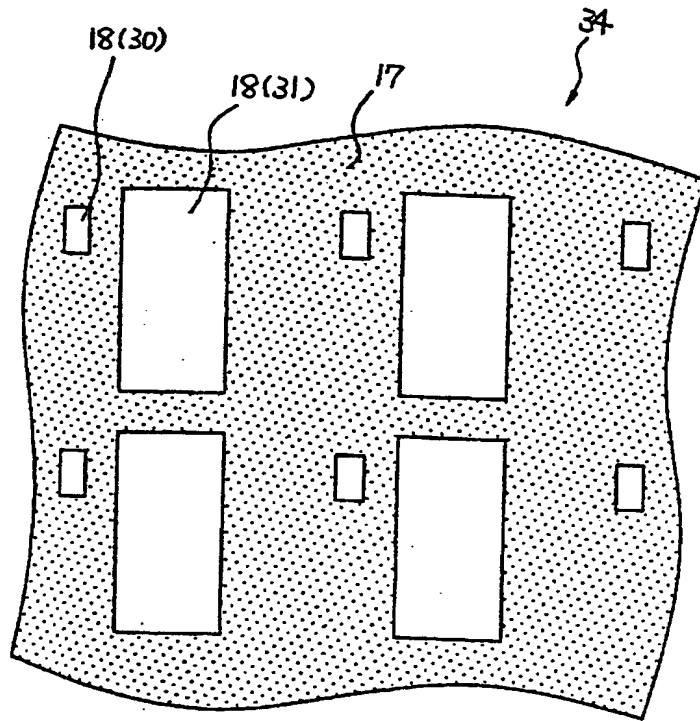
[Fig. 10]



[Fig. 11]

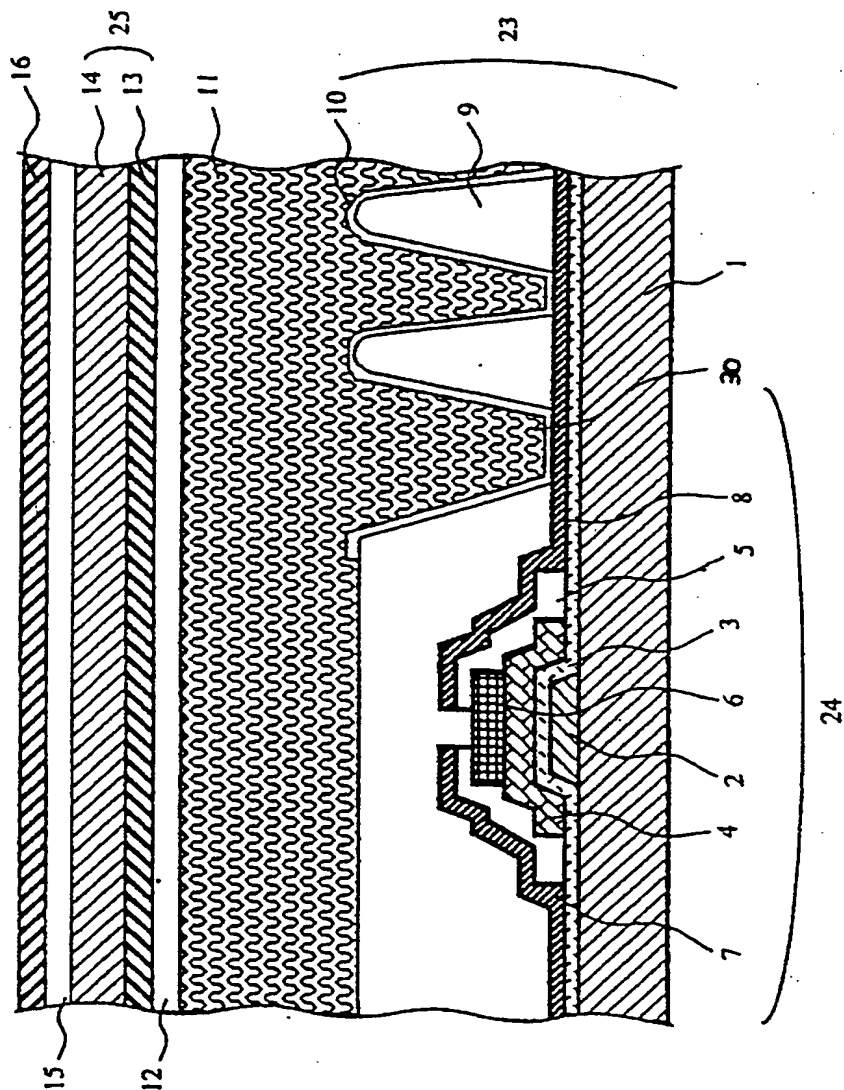


[Fig. 12]

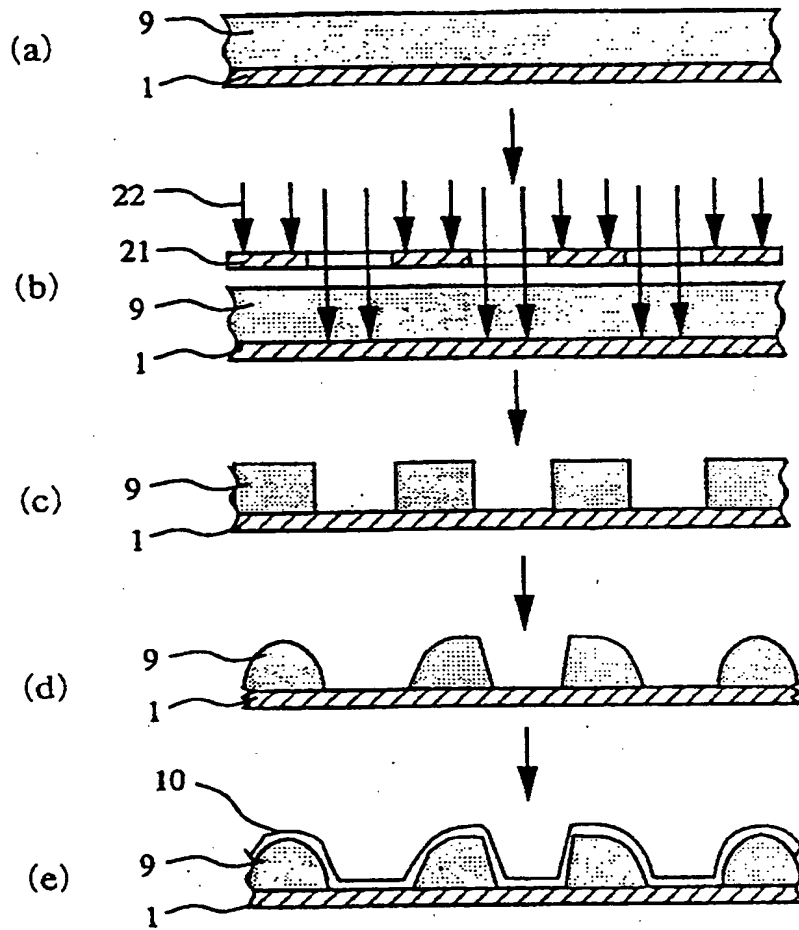


[Fig. 13]

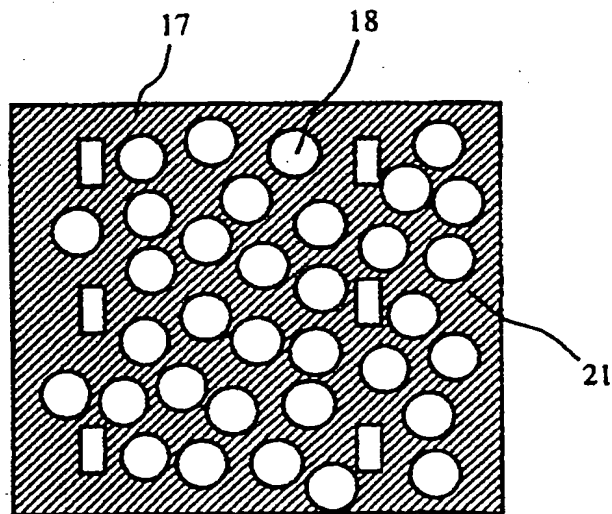
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[Fig. 14]



[Fig. 15]



[DOCUMENT]

ABSTRACT

[ABSTRACT]

[OBJECT] An object of the invention is to provide a method of manufacturing a liquid crystal display apparatus of high display quality by which a reflecting plate having excellent reflection characteristics can easily be manufactured with excellent reproducibility.

[SOLUTION] A positive photosensitive resin is applied to a substrate, asperities are formed in a first region of the applied photosensitive resin film by exposing with various integrals of exposure amount so that the photosensitive resin in the first region is left in different film thicknesses and a concave is formed in a second region of the applied photosensitive resin film so that the photosensitive resin in the second region is left in a thickness smaller than those of the first region by exposing the second region with an integral of exposure amount different from those for the first region.

[FIGURE TO BE PUBLISHED] Fig. 2